Formulation of lubricants: Base oils

Base oils are the fundamental building blocks of a finished lubricating oil or grease, their properties and endurance are depending of their quality. Typically comprise between 80 and 90% of the finished lubricant.

Every base oil meet a series of properties related with its chemical composition, the main ones are:

- **Oxidation stability**, resistance to oxidative degradation promoted by temperature.
- **Thermal stability**, high temperature stability when oxygen/air is not present.
- **Carbon residue**, solid residues, as soot, produced at high temperature.
- **Solvency**, capacity to solve chemical products, as additives or contaminants.
- **Seal compatibility**, base stocks should protect seals.
- **Viscosity index**, or viscosity-temperature relationship.
- **Low-temperature properties**, base stocks should have low wax content, because they have got high poor point.
- **Volatility**, tendency to evaporation, high volatility reduce flash point.
- **Oxidation, corrosion and rust**, base oils should be water and acid free.
- **Colour**, doesn't influence in the final result. Refined base oils are brown-amber coloured, hydro-treated are yellow-golden coloured, synthetic base oils are uncoloured, and heavy based oils are black-greenish coloured.
- **Toxicity**, as much refined are the base oils as low toxicity they are, reaching even no toxic base oils.
- **Biodegradability**, high refined and synthetic base oils are practically biodegradable. The biodegradability is ensured for example by bio-based ester.
- **Demulsibility**, the ability of oil and water to separate.
- **Foam characteristics**, the tendency to foam formation and the stability of the foam results.

1. Mineral base oils

They are manufactured from crude oil, separated by a distillation process in a vacuum column, refining in several stages and various treatments which result in a large variety of medical, cosmetic, industrial and automotive oils and lubricants.

In any case, mineral base oils are combinations of paraffin, iso-paraffin, naphthene, aromatic, and sulphur and nitrogen compounds. According to content in paraffin and iso-paraffin, base oils are called **naphthenic** (content in paraffinic from 42 % to 50 %), **neutral** (from 50 % to 56 %) and **paraffinic** (from 56 % to 67 %).

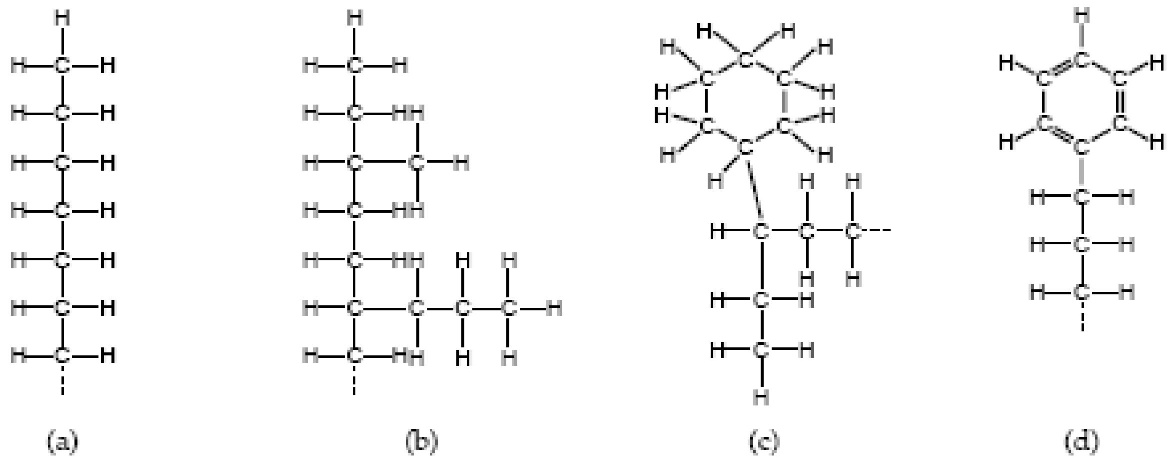

Figure 1 Mineral base oils: (a) – Paraffin (wax), (b) – Paraffin (branched(c) – Naphthene ring, (d) - Aromatic

Mineral base oils provide good lubricity and protection against corrosion, compatibility with seals and paints, natural solvency, hydrolytic stability and low costs.

On the other hand, they have got a low flash point, high pour point, and low oxidation and temperature stability, so the range of operation temperature and duration are limited.

API (American Petroleum Institute, USA) classifies base oils by sulphur content, saturates content and viscosity index.

Usually, **Group I** base oils are produced by refining and de-waxing, but **Group II** and **Group III** are produced by hydrotreating, followed of dewaxing or wax isomerization.

Base Oils	Satures Content	Sulfur Content	Viscosity Index
Group I	<90 %	>0.03 %	80 – 120
Group II	>90 %	<0.03 %	80-120
Group III	>90 %	<0.03 %	>120

Table 1 API Clasification (1st part)

2. Re-refined base oils

Used oils content wear metals, oxidation wastes, particles from combustion, fuel, water and anti-freeze, so the oil should be changed; but the most of molecules of base oil are in good conditions and can be used again. A re-refining process eliminate contaminants and additives to blend a new lubricant.

The regeneration process starts with a **chemical treatment** to bind wear metals and dirt to make their elimination easier. Next, **dewatering** and **vacuum distillation** process remove water and lighter oils. Finally, a **hydrotreating** process introduce hydrogen to remove sulfur, nitrogen, chlorine and oxidation products.

The process produces **Group I** base oils, and can reach **Group II** base oils by high quality hydrotreating.

3. Gas-to-liquids (GTL) base oils

Gas-to-Liquids is a process for converting natural gas into fuels and base oils, GTL process tears natural gas molecules apart and reassembles them into longer chain molecules. The result is an extremely pure base oil, formed by iso-paraffin, free of contaminants such as sulfur, aromatics and metals; that can be considered **Group III** or can be transform to **Group IV**.

Iso-paraffin produced by GTL process provide good viscosity properties, oxidation resistance and good low-temperature conditions.

4. Synthetic base oils

Synthetic base oils are produced, mainly, from low molecular weight hydrocarbons, the process produces high quality and extended service life capability base oils under extremes operating conditions.

In general terms, synthetic base oils are able to handling a wider range of application temperatures, so they provide the best protection both to high and low temperatures.

Base Oils	Type of Base
Group IV	Polyalphaolefin
Group V	Other Synthetic Bases

Table 2 API Clasification (2nd part)

The more usual synthetic base oils are:

a. Synthetic hydrocarbon fluids:

The SHFs comprise the fastest growing type of synthetic lubricant base stock, they all are compatible with mineral base stocks.

Polyalphaolefins (PAO) are unsaturated hydrocarbons with the general formula $(-CH_2-)_n$, free of sulphur, phosphorus, metals and waxes. Provide excellent high temperature stability and low temperature fluidity, high viscosity indexes, low volatility and compatible with mineral base oils. Although the oxidation stability is lower than mineral oils and their solvency of polar additives is poor, so usually PAOs are combined with other synthetic oils.

This base oil is recommended for engine oils and gear oils.

Alkylated aromatics formed by alkylation of an aromatic compound, usually benzene or naphthalene. Provide excellent low temperature fluidity and low pour points, good solubility for additives, thermal stability and lubricity. Although their viscosity index are about the same as mineral oils, they are less volatile, more stable to oxidation, high temperatures and hydrolysis. They are used as the base of engine oils, gear oils and hydraulic fluids.

Polybutenes are produced by controlled polymerization of butenes and isobutylenes. Compared with other synthetic base oils are more volatile, less stable to oxidation and their viscosity index is lower; their tendency to produce smoke and shoot deposits is very low so they are used to formulate 2-Stroke engine oils, also as gear oils combined with mineral or synthetic base oils.

b. Polyalkylene glycols (PAG):

PAG are polymers made from ethylene oxide (EO), propylene oxide (PO), or their derivatives. Solubility in water or other hydrocarbon is depending the type of oxide.

Both provide good viscosity/temperature characteristics, low pour point, high temperature stability, high flash point, good lubricity, good shear stability, PAGs are not corrosive for the most of metals and compatible with rubber.

Main disadvantages are low additive solvency and pour compatibility with lubricants, seals, paints and finishes.

They are used as a base for hydraulic brake fluids (DOT3 and DOT 4) due their water solubility, 2-stroke engine oils due the low deposits at high temperatures, compressor lubricants and fire-resistant fluids.

c. Synthetic esters:

They are oxygen-containing compounds that result from the reaction of an alcohol with an organic acid. They have good lubricity, temperature and hydrolytic stability, solvency of additives and compatibility with additives and other bases. But some esters can damage seals so require special compositions.

They are used as base oils for engine oils, mixed with other synthetic bases, because improve low temperature properties, reduce fuel consumption, increase wear protection and viscosity-temperature properties.

Also, as 2-Stroke engine base oils, they reduce deposit formation, protecting rings, pistons and sparks. The allow to reduce the quantity of lubricant from 50:1 of mineral oils to 100:1 and up 150:1 due their outstanding lubricity.

Phosphate esters are used as anti-wear additives due their high lubricity and as base oils for hydraulic fluids and compressor oils due their low flamability. But their hydrolytic and temperature stability and viscosity index is low and their low temperature properties are poor. Also they are aggressive with paints, coats and seals.

Polyol esters have good high temperature stability, hydrolytic stability and low temperature properties, low volatility and low Viscosity Index; the polyol esters also may have more effect on paints and cause more swelling of elastomers. To take advantage of their miscibility with hydrofluorocarbon (HFC) refrigerants, polyol esters are used in refrigeration systems.

d. Polyethers:

In this group we can find **Perfluorinated polyethers** (PFPE) with a density nearly twice that of hydrocarbons, they are immiscible with most of the other base oils and non-flammable under all practical condition. Very good viscosity-temperature and viscosity-pressure dependence, high oxidation and water stability, inert chemically and radiation stable; these properties joined their shearing stability. They are suitable as hydraulic fluids in spacecraft and as dielectric in transformers and generators.

Polyphenyl ethers have excellent high temperature properties and resistance to oxidation but they have fair viscosity-temperature properties, they are used as hydraulic fluid for high temperture and radiation resistence.

Polysiloxanes or **Silicones** have high viscosity index, over 300, low pour point, high temperature stability and oxidation stability so run well in a wide range of temperatures; they are chemically inert, non-toxic, fire resistant, and water repellent, they have low volatility and are compatible with seals and plastics. Their disadvantage are formation of abrasive silicon oxides if oxidation does occur, effective adherent lubricating films are not formed due their low surface tension, and also show poor response to additives. They are used are brake fluids and as anti-foam agents in lubricants.

The table compare different synthetic base oils properties against mineral oil:

Base Oils	Viscosity Index	Low Temperature Properties	High Temperature Properties	Mineral Oils Compatibility	Low Volatility	Coat Compatibility	Hydrolytic Stability	Anti-Corrosion Protection	Additives Solubility	Seals Compatibility
Minerals	F	P	F	E	F	E	E	E	E	E
PAOs	G	G	VG	E	E	E	E	E	G	E
Alkylates	F	G	G	E	G	E	E	E	E	F
Polyalkylene Glycols	VG	G	G	P	G	G	VG	G	F	G
Esters	G	G	G	G	E	P	F	F	VG	F
Silicones	E	G	G	P	G	VG	G	G	P	E

E : Excellent; VG: Very Good; G: Good; F: Fair; P: Poor

Table 3 Comparison among base oils

5. Bio-bases oils

They are mainly produced from soybeans, rapeseed, palm tree, sunflowers and safflowers. Their advantages are high biodegradability, superior lubricity, higher flash point and viscosity index; but their pour point is high and the oxidative stability is poor, also the recycling is difficult.

Main applications are hydraulic fluids, transmission fluids, gear oils, compressor oils and greases. Better when application is total loss, indoors or where low pour point is not an issue, food industry or environmentally-sensitive areas.